Selected topics of H->ττ analyses relevant to early data taking

A. Nikitenko, Imperial College

for Theory-Experiment interplay workshop in Univ. of London, Royal Holloway, 8-9 April

Working Model for 2010 dataset

	Month	Linst (peak) [ave. of month]	Delivered Lumi (/pb/month) [end. of month]	Sum Delivered (/pb)
April	2	8.6E29	0.5	0.5
May	3	2.0E30	1.0	1.5
June	4	4.8E30	2.5	4
July	5	1.2E31	6	10
Aug	6	2.7E31	15	25
Sept	7	6.5E31	35	60
Oct	8	1.0E32	50	110

accumulate ~ 1 fb^{-1} by the end of 2011

Selected topics

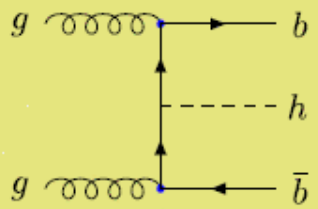
- Z+1b as benchmark for SUSY H+1b
- Energy calibration of tagging quarks for VBF H
- Rapidity gap selection methods in VBF H
- Z+jets background to VBF H->$\tau\tau$ from double parton scattering

Z+1b as benchmark for SUSY H+1b

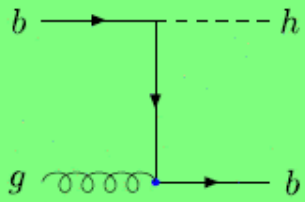
H+1 b

$H + b$ calculations — Slide from J. Campell talk

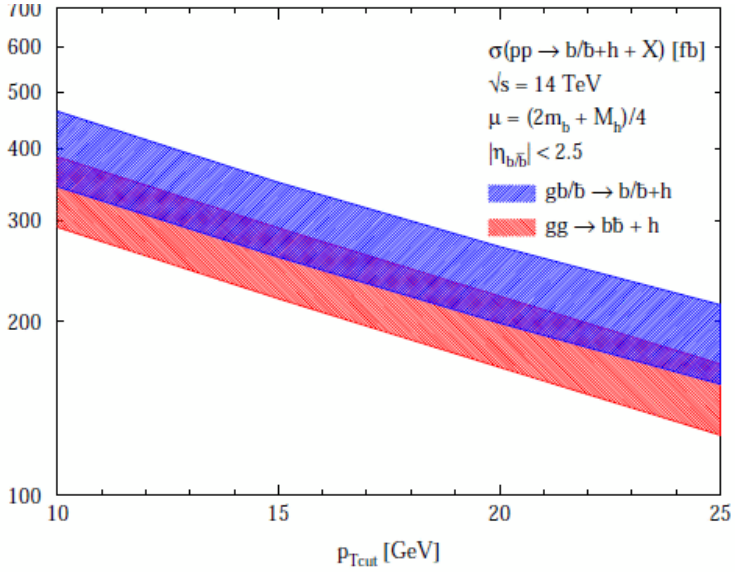
- Use the $gg \to H b\bar{b}$ process and perform the calculation with the b-quark massive.
- The collinear divergence in the $g \to b\bar{b}$ splitting is regulated by the mass, so one can compute the rate when only one b-quark is observed.
- No b-quark PDF $\longrightarrow$ "4-flavour scheme".



- Absorb the gluon splitting into the b-quark PDF, so the basic process is $gb \to Hb$.
- There is no need to retain the b-quark mass.
- Large logarithms of the form $\alpha_s \ln(m_H^2/m_b^2)$ are resummed into the b-quark PDF, hence "5-flavour scheme".



Approaches should agree; both can be calculated at NLO.



Cut on p_T^b, M_H=120 GeV

Les Houches 2003 (hep-ph/0405302):

5F scheme (Campbell, Ellis, Maltoni, Willenbrock);

4F scheme (Dittmaier, Kramer, Spira, Dawson, Jackson, Riena, Wackeroth)

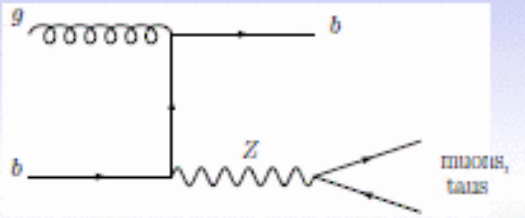
LHC xs adreed within ~ 20 % uncertainties due to variation of μ_F, μ_R by factor 2

Z+1 b

$Z + b$ as a test case

Slide from J. Campbell talk

- The production of $Z + b$ is very similar to that of $H + b$, even lying in a similar kinematic region for a low mass Higgs.
- Theoretically, the two processes have the same inputs and uncertainties.
  - same initial state, similar (x, Q^2)
  - the same H and Z decays

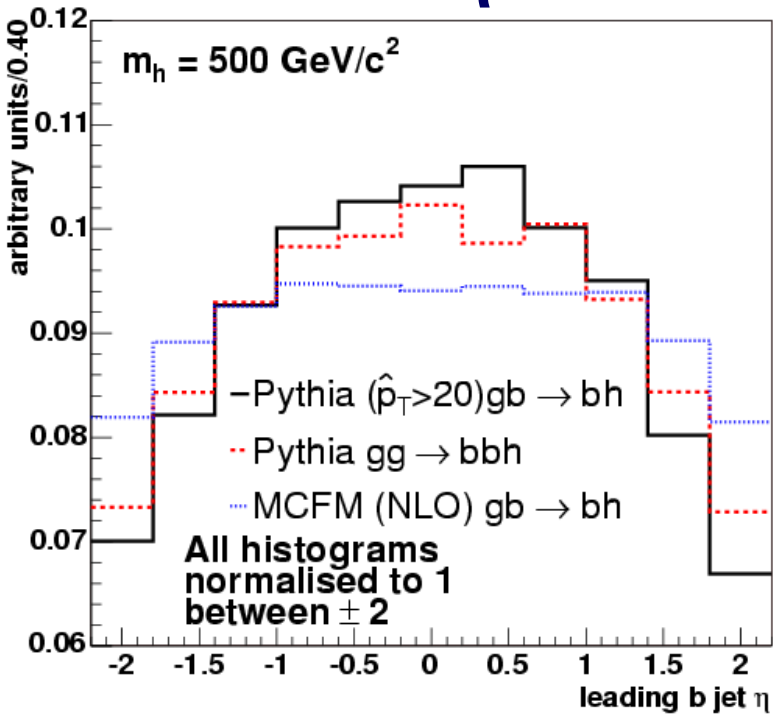


- Test the experimental analysis procedure by re-discovering the Z –
  a) $Z+$ one jet which is b-tagged ;
  b) $Z+$ two jets, one or more b-tags.
- Furthermore, for low Higgs masses a significant source of background events could come from the production of a slightly off-shell Z boson and a bottom quark at high p_T.

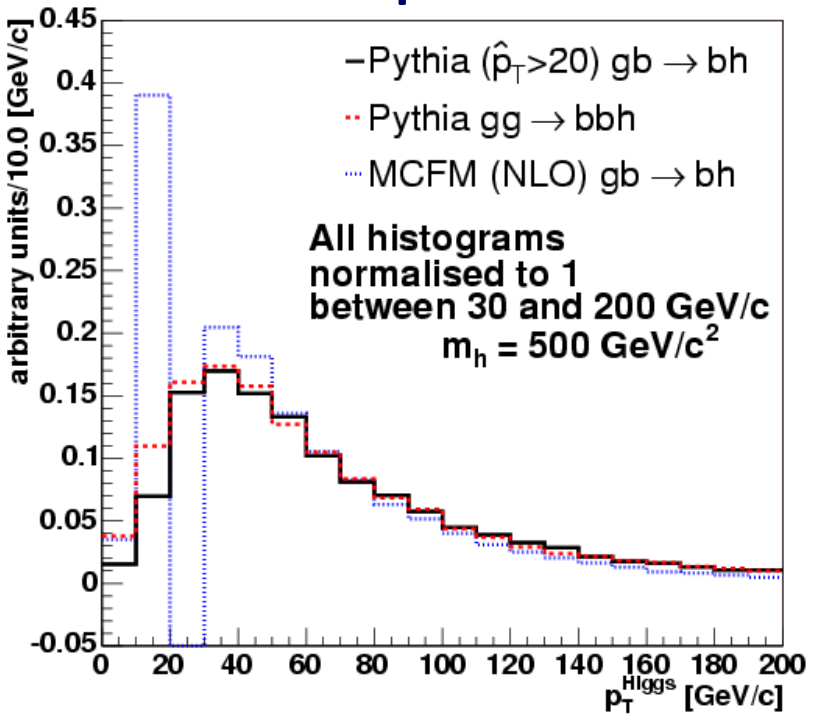
Different MCs for b(b)H production gives different predictions: => need bbZ data to tune/verify Monte Carlo

Campbell, Kalinowski and Nikitenko; Les Houches 2005 hep-ph/0604120

η^b



p_T^H



PYTHIA gg->bbH describes p_T^b spectra at NLO within 5-10 %;
Kinnunen, Lehti, Moortgat, Nikitenko, Spira. Eur.Phys.J. C40n5:23-32,2005

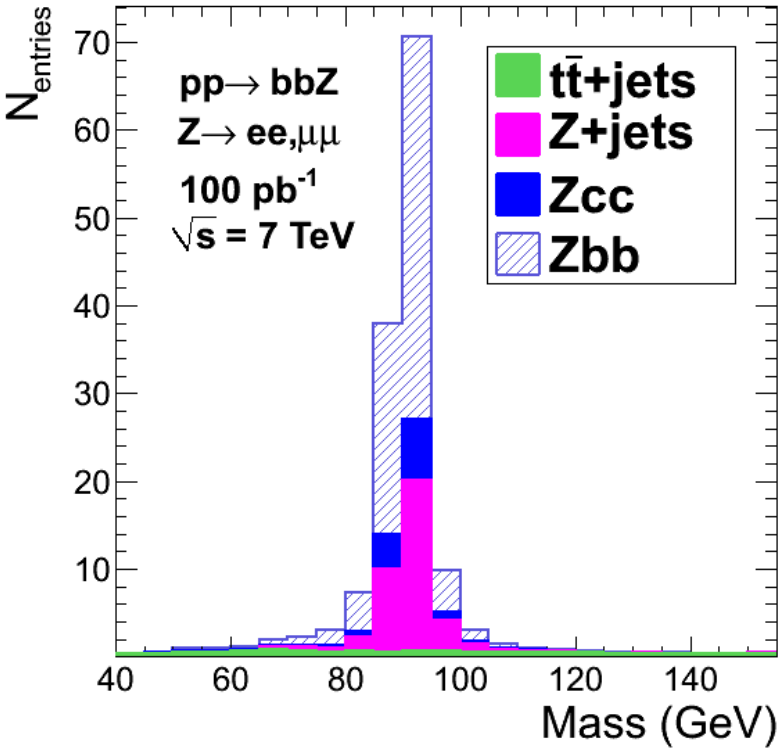
want to measure Z + 1(2) b + X

- **at least 1 b tagged jet**
  - **Campbell, Ellis, Maltoni, Willenbrock, McElmurry hep-ph/0312024, hep-ph/0505014. $m_b = 0$**
- **at least two jets with at least 1 b-tagged jets**
  - **Campbell, Ellis, Maltoni, Willenbrock hep-ph/0510362, $m_b=0$**
- **at least two jets with 2 b-tagged**
  - **Cordero, Reina, Wackeroth arXiv:0906.1923 [hep-ph],massive b**
- ***MagGraph generator preselections (agreed with F. Maltoni):***
  - ***LO gg->bbZ with massive b; $p_T^b > 10$ GeV for at least one b***
  - ***corresponding σ NLO needs 4- and 5-flavour merging. L. Rieina, F. Cordero – work in progress***

CMS expectations for Z+1b at 7 TeV
(rescaling 10 TeV result)

A.M. Magnan, A. Nikitenko . CMS Analysis Note 2010/027

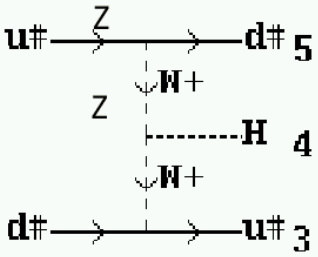
- 2 l p_T > 20 GeV, $|\eta|$<2.1
- E_T^{miss} < 40 GeV
- >= 1 b-jet, E_T>15 GeV, $|\eta|$< 2.1
- N_S = 84 ev.
- *Background:*
  - *Z+jets: 39 ev.*
  - *Z+cc: 14 ev*
  - *tt~: 15 ev*



How Z+1(2)b can help SUSY H+1b measurement ?

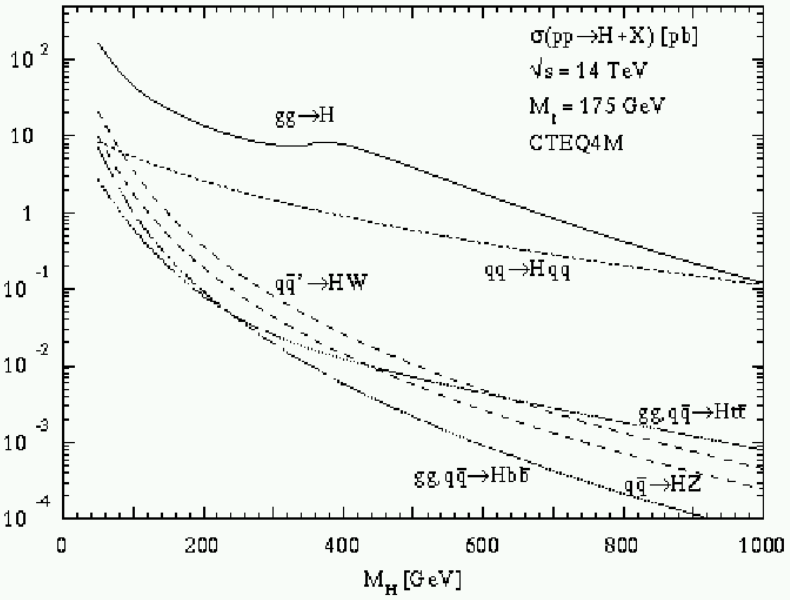
Energy calibration for tagging quarks in VBF H

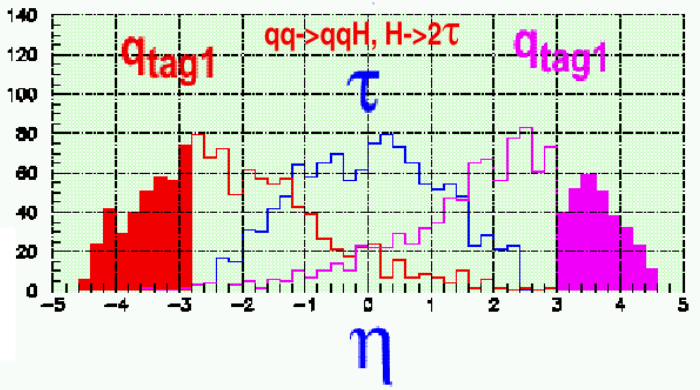
VBF : qq->qqh process



- large enough rates
- forward jet tagging and mini-jet veto for low L
- central Higgs decay products to trigger
- not too big bkg, S/B ~ 1

D. Zeppenfeld and collaborators are discussing it since ~ 10 years





- **first idea was to use W->qq from tt~**
  - J.D'Hondt, P. Van Mulders, CMS Analysis Note 2007/029. but small stats. at high η

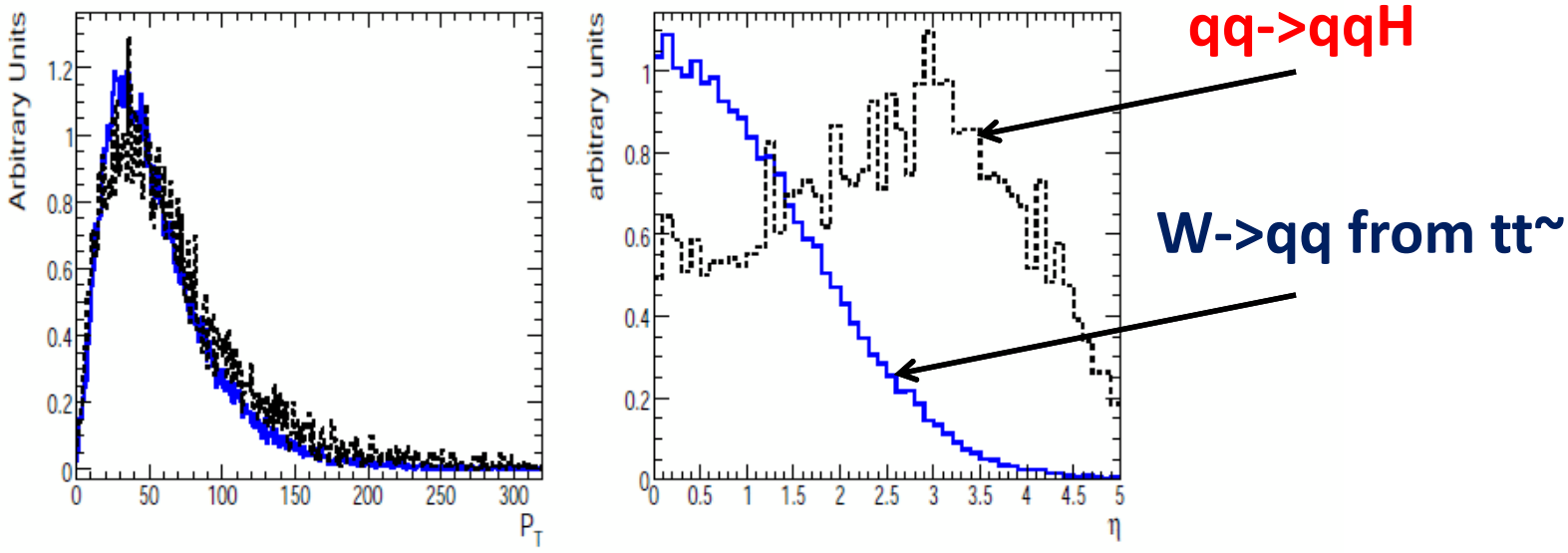
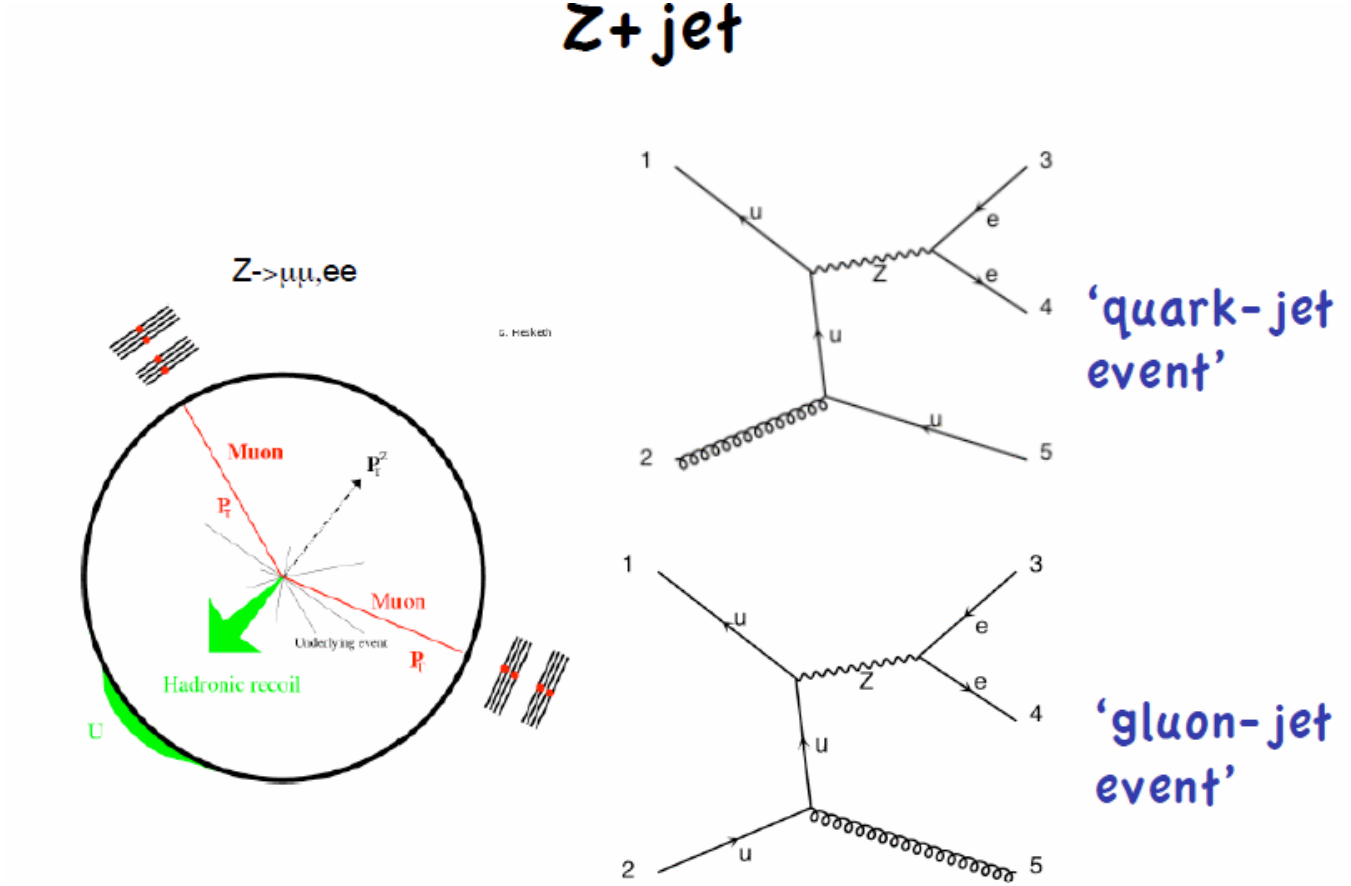


Figure 18: Transverse momentum and η distribution of tagging quarks from VBF Higgs boson production (dashed line) and quarks from W decays in $t\bar{t}$ events (solid line).

- **another proposal is to use Z+1j events**
  - A. Nikitenko, E. Yazgan CMS Analysis Note 2010/044

Z+1j, j = q or g jet



The Method

The calibration coefficients for the quark jets, c_q, can be obtained from:

(see the back-up slides for a simple derivation)

$$C(E^j_{T,raw}, \eta^j) = \frac{p^Z_T}{E^j_{T,raw}} = \frac{c_q}{w_q + k^{q/g} w_g}$$

measure

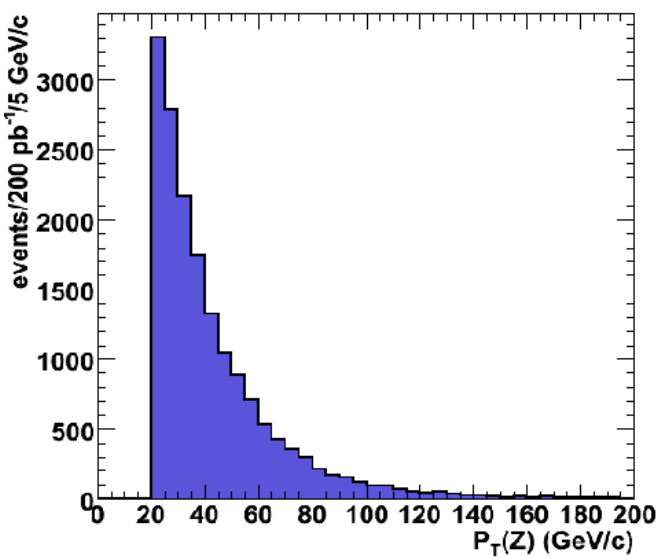
c_q/c_q=ratio of the quark And gluon jet calib. Coefficients from MC (E_T^j and η^j dependent)

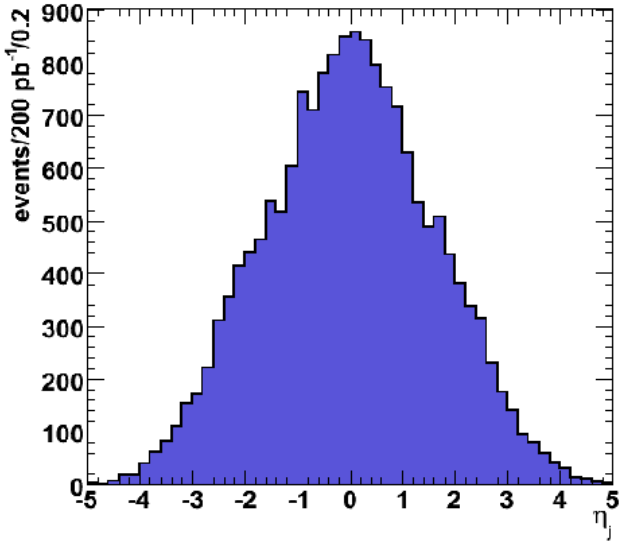
$\sigma(Z+q)/\sigma_{TOT}$

$\sigma(Z+g)/\sigma_{TOT}$

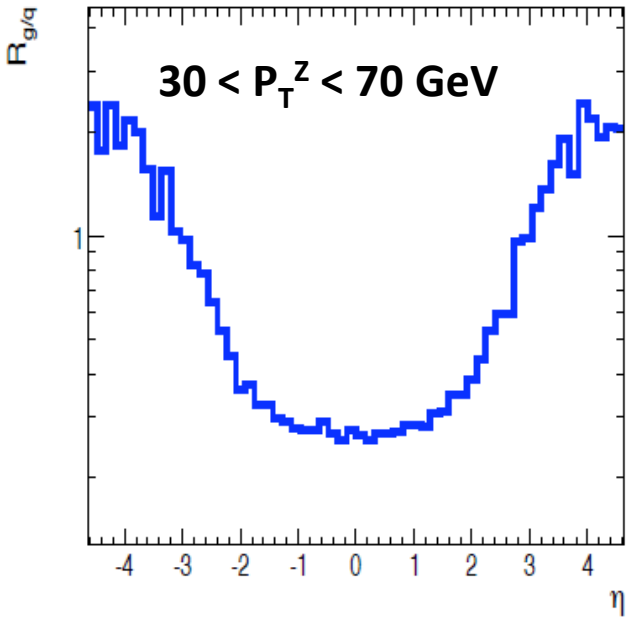
Ratio of Z+q (Z+g) Cross section to the Total cross section. (function of P_T^Z and η^j)

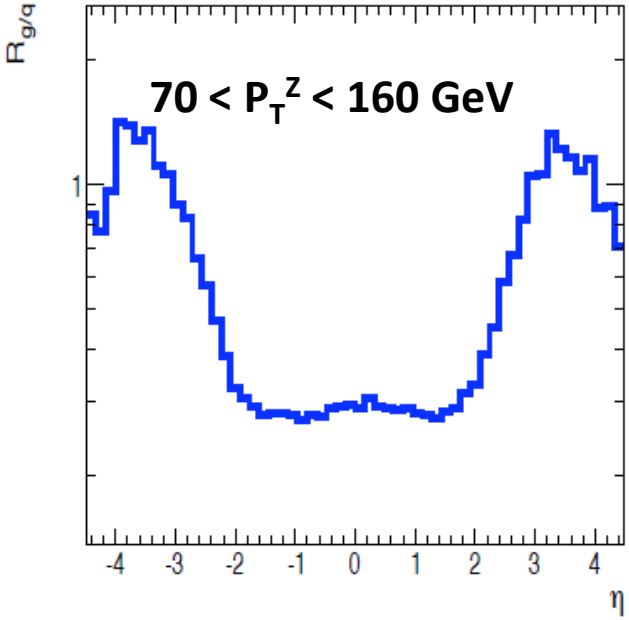
data input: 200 pb^{-1} at 10 TeV (for 7 TeV rescale by ~ 1.7)





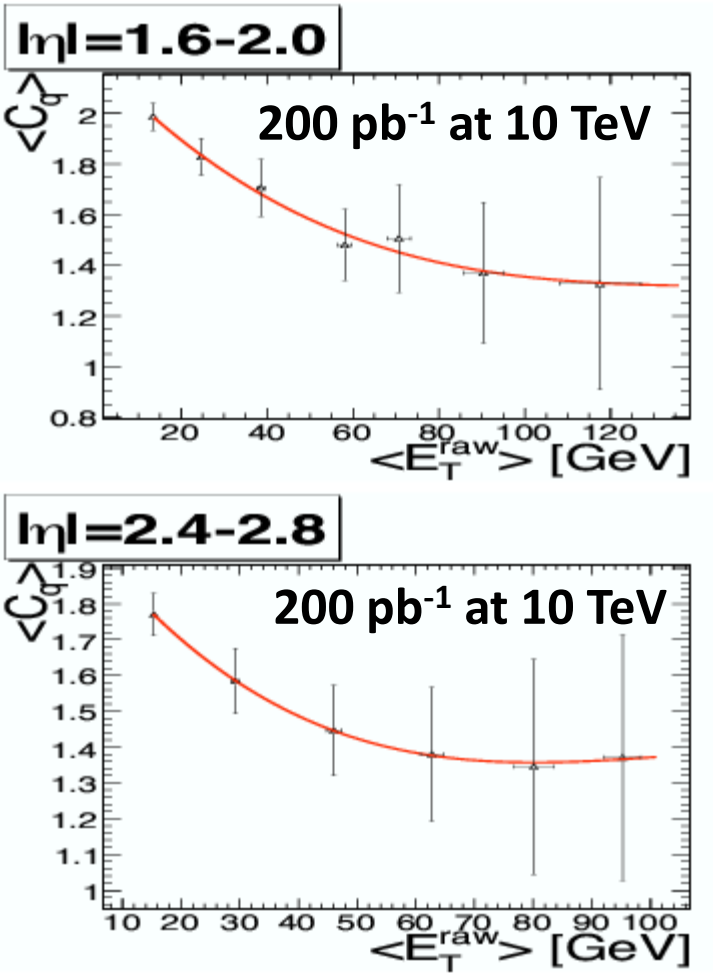
theory input: Ratio of Z+g and Z+q cross-sections



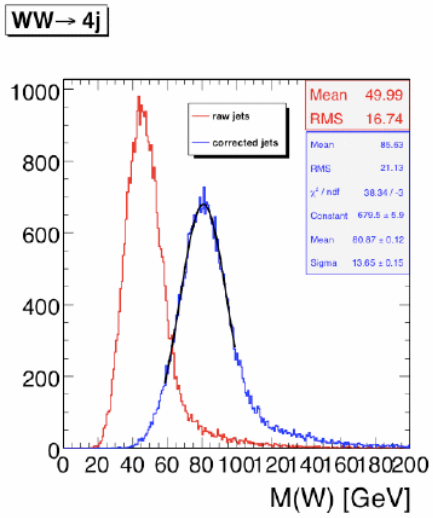


Results obaines with MadGraph Z+jets events

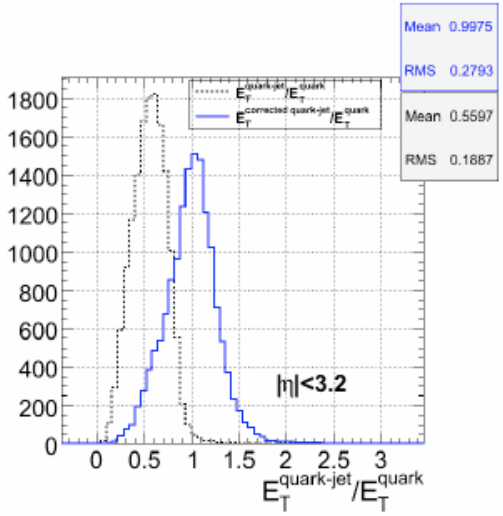
(with MLM matching)

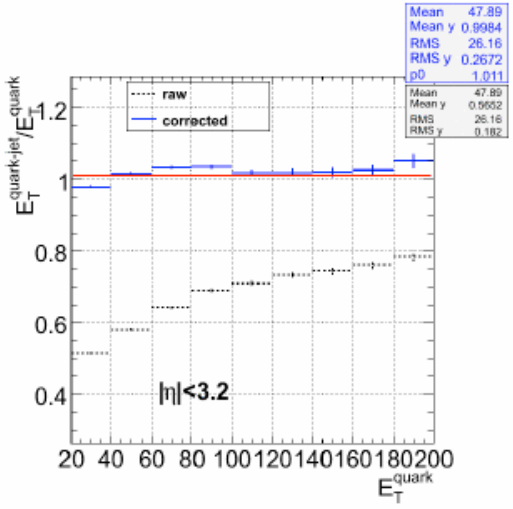


Test of Quark Coefficients: WW→ 4q→4j



Test of Quark Coefficients: Consistency Check





- Overall Mean (raw) = 0.56 GeV, Mean (corr) = 1.00 GeV
- Rms/mean = 0.34 (raw), rms/mean = 0.28 (corr)
- Corrections restore the quark jet response with fluctuations of ≤5% around 1 (<~3% for E_t^{quark} <180 GeV).

Calibration uncertainty

- **Statistical**
  - **shown on previous slide**
- **Theoretical**
  - **$\sigma(Z+g)/\sigma(Z+q)$ uncertainty**
    - **Did not find in literature. Can assume the same uncertainty as for $\sigma(z+1j)$ at LO , ~10 % from Campbell, Keith, Rainwater hep-ph/0308195**

Does this calibration make sense for theorists ?

Central rapidity gap selection for VBF H analysis

Rapidity gap in VBF (WW->H) production

first discussed in :

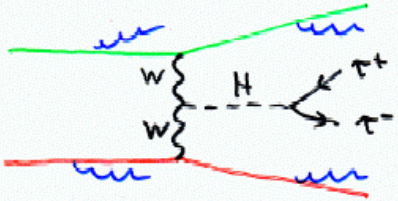
Yu. Dokshitzer, V. Khoze and S. Troyan, Sov.J.Nucl. Phys. 46 (1987) 712

Yu. Dokshitzer, V. Khoze and T. Sjostrand, Phys.Lett., B274 (1992) 116

From D. Zeppenfeld talk on TeV4LHC, 2004

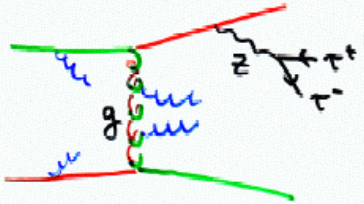
Gluon emission in WBF events

Color singlet exchange in t-channel
⇔"synchrotron" radiation between
initial and final quark direction

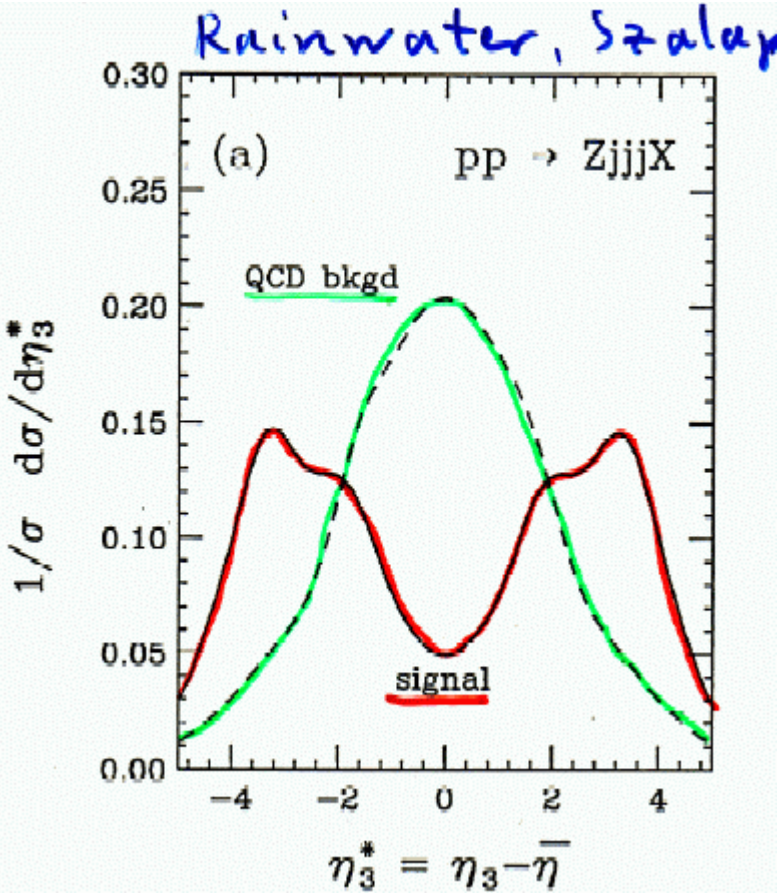


⇒ central jets suppressed

Major backgrounds : t-channel color exch



deflection of color charge by ~ 180°
⇒ central gluon emission



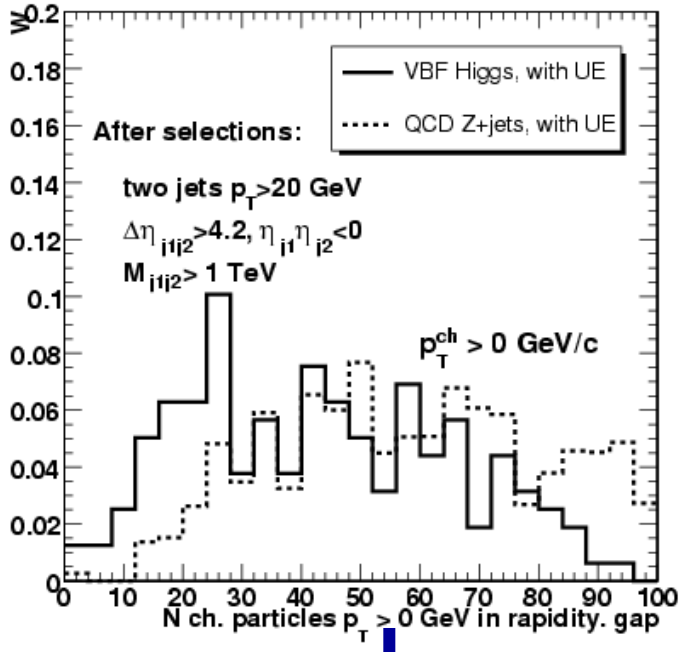
Methods for central rapidity gap selection in CMS VBF Higgs analyses

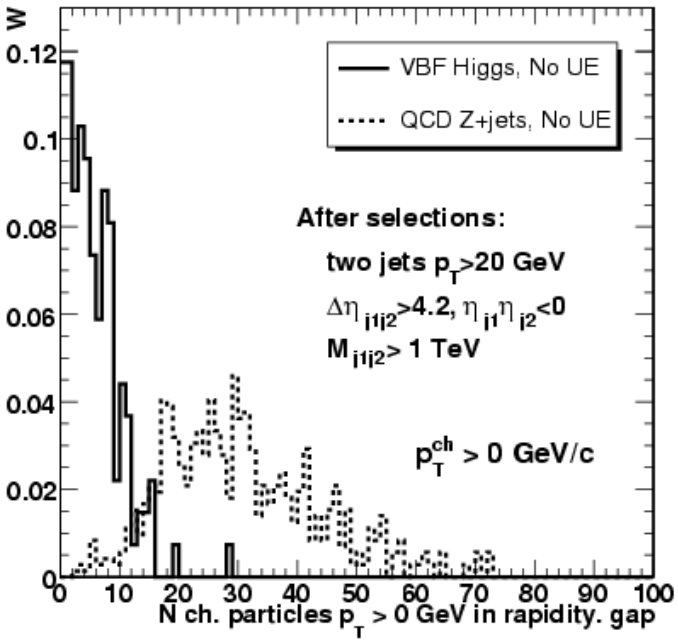
- **Central Jet Veto (CJV) in VBF Higgs analyses was firstly proposed and used, in particular in**
  - **D. Zeppenfeld et al. "Searching for H->tau tau in weak boson fusion at LHC", Phys. Rev., D59 (1999), 014037**
  - **The CJV is suffering from the pile up and electronic noise**
  - **the "α" method for fake jet reduction using the information from the vertex and tracks was proposed and described in**
    - **CMS Note 2006/088, N. Ilina, V. Gavrilov and A. Krokhotine**
  - **the "α" method was used in PTDR qqH and inclusive H->WW analyses**
- **Track Counting Veto (TCV) . It was inspired by the paper**
  - **Y.L. Dokshitzer, V.A. Khoze and T. Sjostrand, "Rapidity gaps in Higgs production", Phys. Lett. B274, 116-121, 1992**

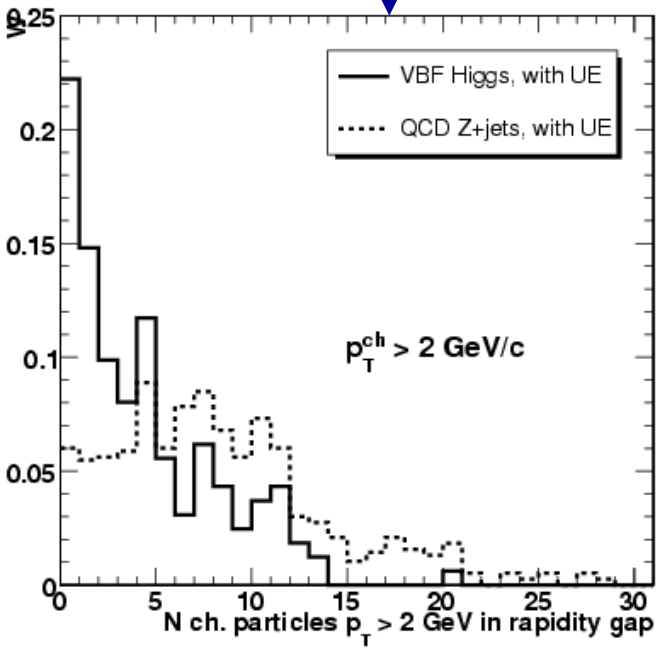
TCV method:

count tracks from PV between tagging jets and select events with $N_{trk} < N_{trk}^{cut}$

Gen. level plots



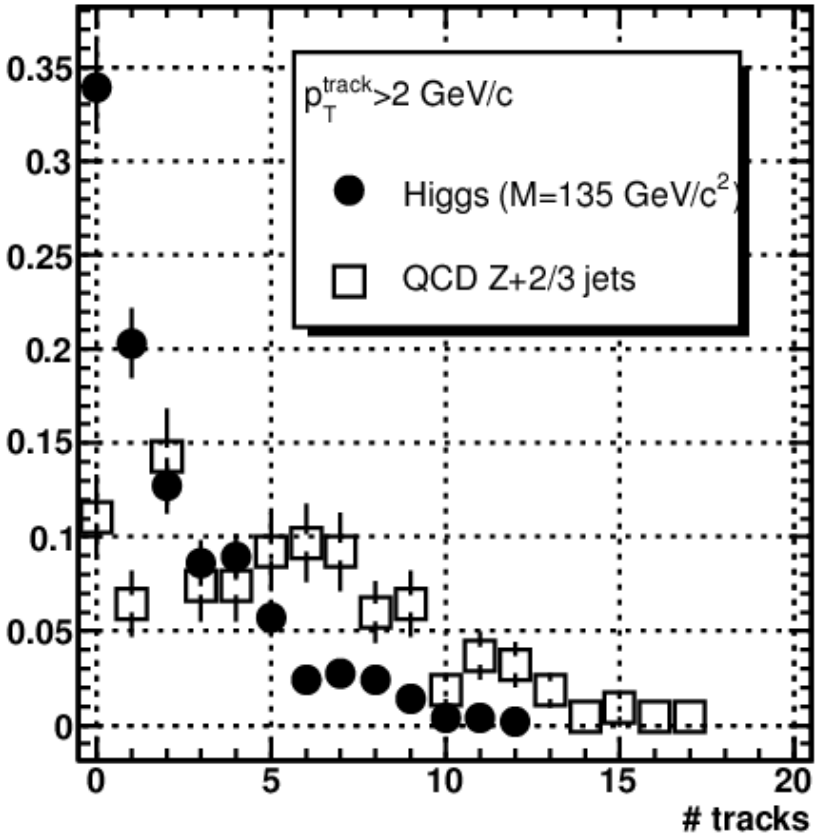


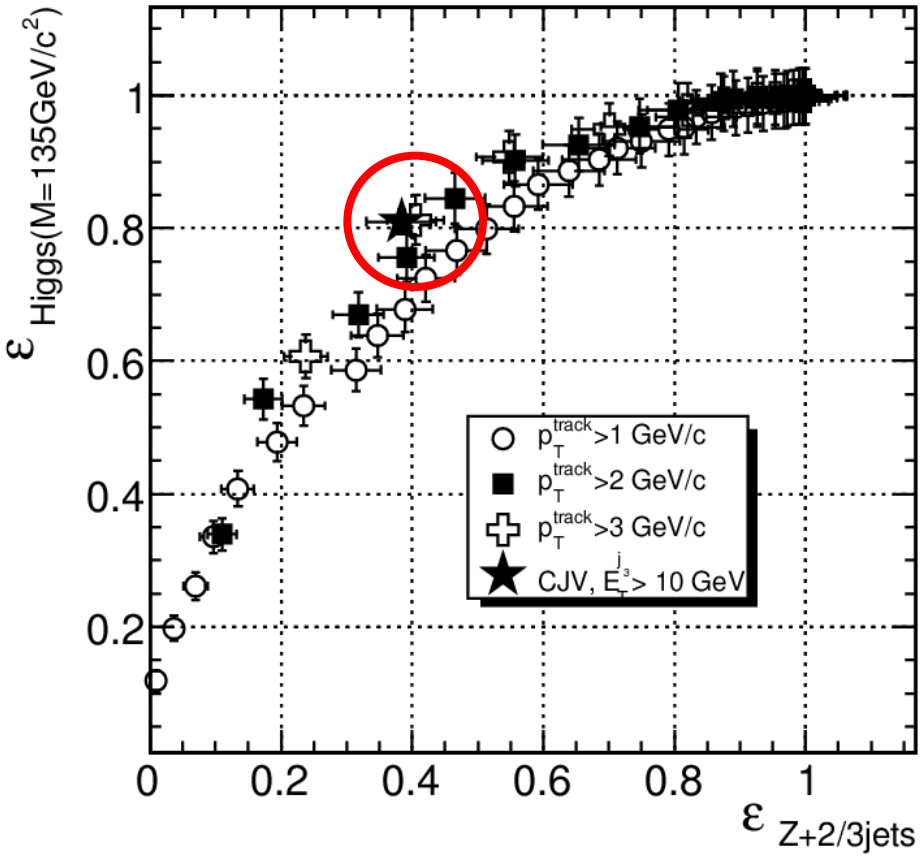


Reco level with pile up, L=2x10^{33} cm^{-2}s^{-1}

re-analyzed data from PTDR qqH, H->ττ analysis

CMS Analysis Note 2007/035, CMS-PAS-HIG-08-001, arXiv:0803.1154 [hep-ph]





TCV can reach the similar performance as CJV

Measure CJV or TCV with data Z+>=2 jet

- $E_T^j > 40$ GeV, $|\eta^j| < 4.5$, $\eta^{j1} x \eta^{j2} < 0$
- "Soft" VBF: $M_{j1j2} > 400$ GeV, $|\Delta\eta_{j1j2}| > 2.5$
- "Hard" VBF: $M_{j1j2} > 800$ GeV, $|\Delta\eta_{j1j2}| > 3.5$

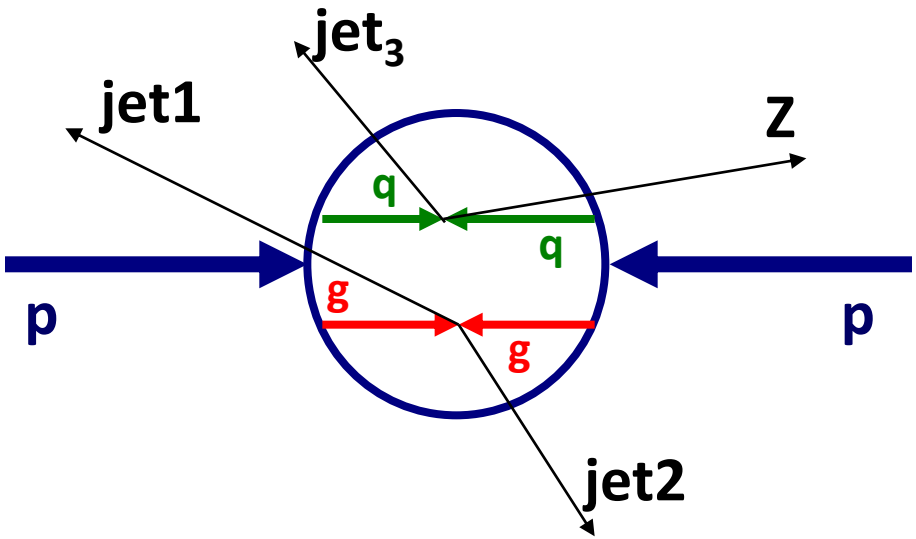
Selections	Events with 1 fb^{-1} at 14 TeV	
	QCD Z + 2 j	*QCD+EWK Z+2 j*
"soft VBF"	1391	1496
"hadr VBF"	278	334

Rescale by ~ 2.2 for 7 TeV

Does TCV make sense for theorists ?

Z+jets background from DPS

Hard double parton interactions can produce an additional Z+jets background to qqH, H->ττ signal



$\sigma^{D}_{(A,B)} = (m/2)\,\sigma_A\sigma_B / \sigma_{eff}$, (m=2 for A=Z, B=di-jets)

σ_{eff}=16.4 mb

from D0 γ+3j analysis: arXiv:0912.5104

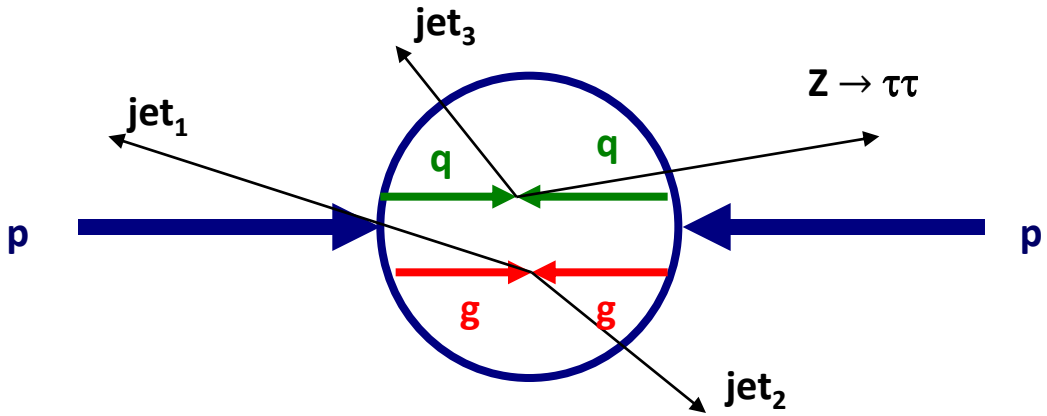
Expectations at LHC: σ_{eff} ~20 mb (T. Sjostrand, private communication)

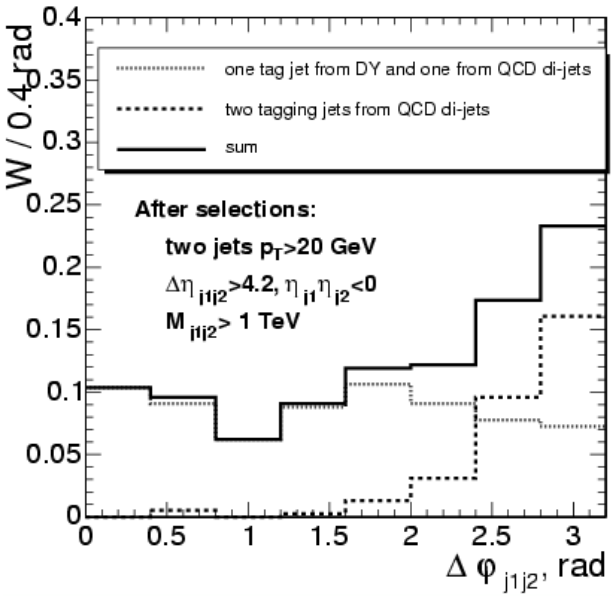
~12 mb (D. Treleani, talk on CMS QCD meeting)

Longitudinal correlations in double-parton PDF can have sizable effect (Snigirev, arXiv;1001.0104 [hep-ph] , Gaunt, Stirling arXiv:0910.4347 [hep-ph])

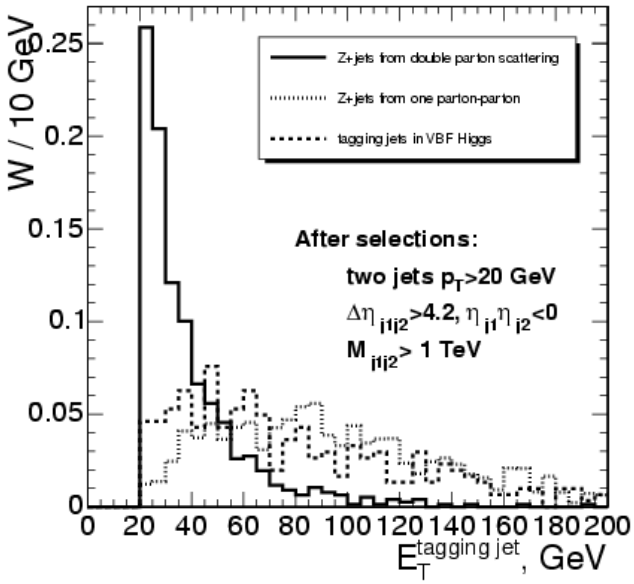
T. Sjostrand recipe to generate DPS with PYTHIA 6 was used

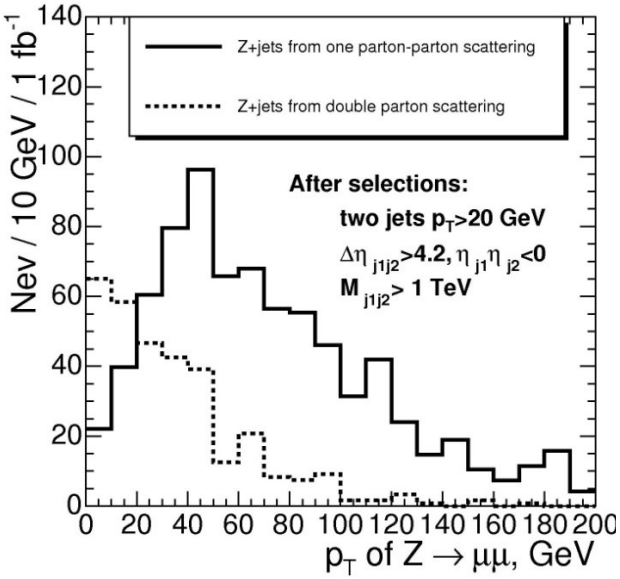
- "generate DY with full UE
- generate the di-jet with MSTP(81)=0 (UE is OFF). [Here at first remove all low p_T particles, say below 1 GeV. Then add a few of them back in, chosen to ensure that the retained event balances p_T to good enough precision. (This is easy to do iteratively, each time adding the particle that reduces the length of the pTmiss vector most.)] – was not done
- Graft event 2 into event 1"

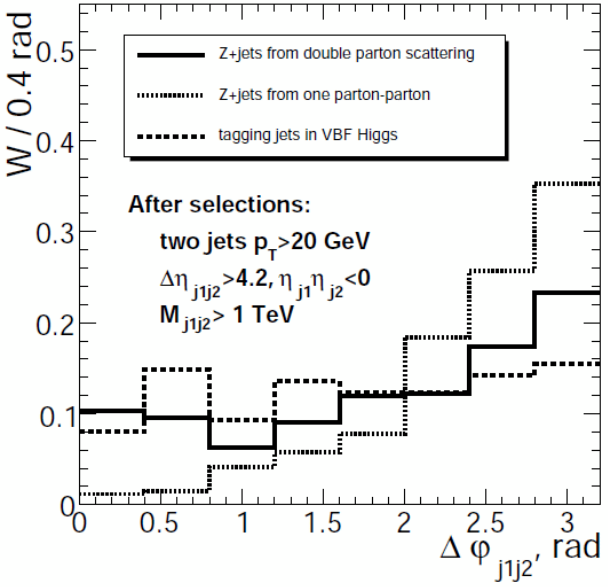




CMS Analysis Note 2007/035, arXiv:0803.1154 [hep-ph]







40 % of "normal" Z+jets after cuts: E_T^j > 20 GeV, M_{j1j2}>1TeV, $\Delta\eta_{j1j2}$>4.2

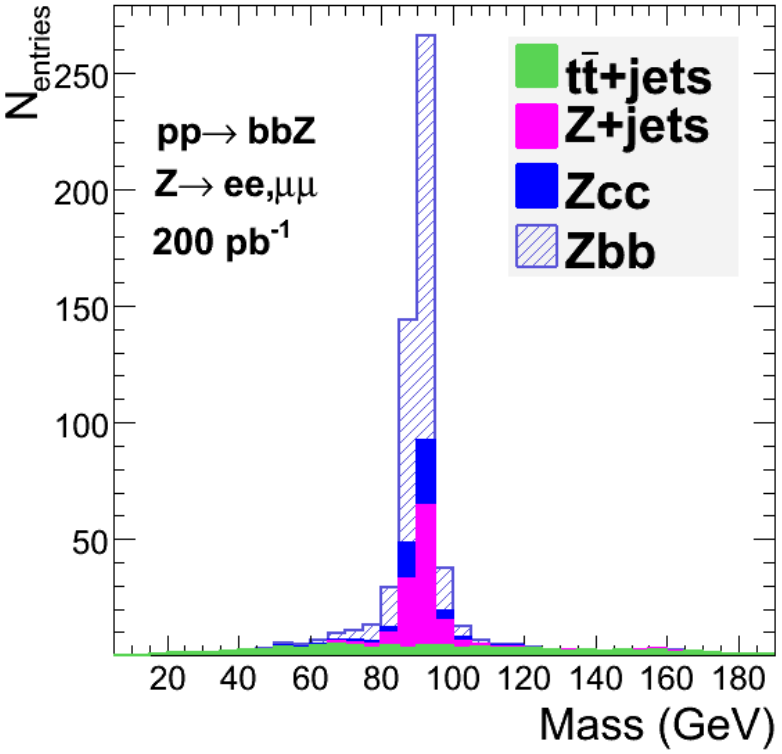
15 % of "normal" Z+jets after cuts: E_T^j > 40 GeV, M_{j1j2}>1TeV, $\Delta\eta_{j1j2}$>4.2

BACKUP SLIDES

CMS expectations for Z+1b at 10 TeV (rescale by ~ 2 for 7 TeV)

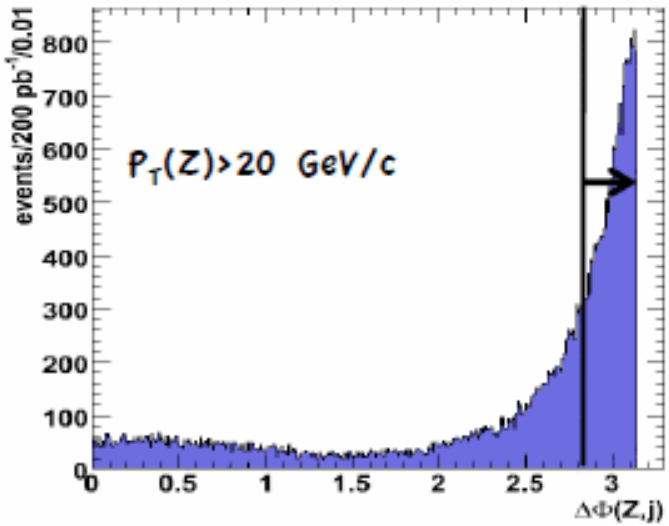
A.M. Magnan, A. Nikitenko . CMS Analysis Note 2010/027

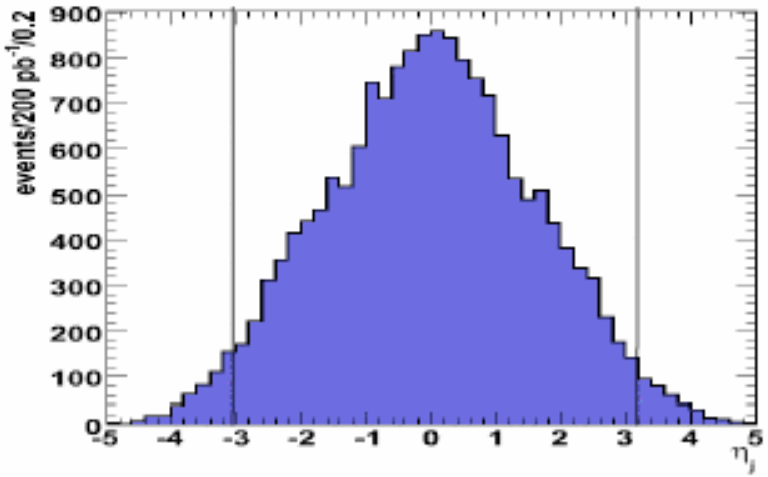
- 2 l p_T > 20 GeV, $|\eta|$<2.1
- E_T^{miss} < 40 GeV
- >= 1 b-jet, E_T>15 GeV, $|\eta|$< 2.1
- N_S = 320 ev.
- *Background:*
  - *Z+jets: 111 ev.*
  - *Z+cc: 52 ev*
  - *tt~: 23 ev*



How Z+1(2)b can help SUSY H+1b measurement ?

Z & Jet Back to back





Low statistics at HF at 200 pb^{-1}.